Compact infrared spectrograph

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Ion Optics, Inc.
Optical Gas Sensors for a Better Tomorrow

Project Overview

- **Project description**
  - Develop small, low-power infrared monitoring components for volatile organic compounds in industrial settings.

- **Objectives**
  - Demonstrate achievable sensitivity for miniature spectrometers
  - Evaluate measurement error sources for field operation
  - Develop improved and demonstrate improved components

- **Overall goal**
  - Improve the effectiveness and reduce the cost of environmental compliance monitoring for industries of the future

Technical Merit

- **Addresses technical need(s) of the S/C community and the S/C priorities of the IOFs**
  - Regulatory compliance (EPA method 21) tests are awkward, time-consuming, and costly
  - Current point detection (valve stems, pumps) methods under-report significant VOC leaks from other sources -- pipes, heat-exchangers, and lube-oil vents
  - Recent plant leak imaging/spectroscopy data (TERC, 2002) suggests that less than 1% of components surveyed produced out-of-compliance VOC leaks
  - Rapid identification (hopefully remote, hopefully unattended) of emission sources will reduce emissions while reducing cost of compliance

Technical Merit

- **Contributes new information or technology to the S/C community**
  - Mid-IR spectroscopy: sensitive and powerful tool for gas detection
  - New photonic components: better point- and stand-off detection
  - Spectral data: multiple or unknown targets, cluttered background
  - Image data: survey and identification of potential leak sites
  - Mid-IR: plume temperature, background spectral content
  - Need correlated Mid-IR image and spectral data
  - Throughput (sensitivity/specificity) + alignment for field unit

Technical Progress and Outlook

- **Major progress/accomplishments to date**
  - ***Defined baseline VOC plume monitor requirements***
  - ***Developed model for Mid-IR spectral + temp contrast***
  - ***Validated model/instrument package with field measurements***
  - ***Brassboard unit: achievable alignment and throughput***
  - ***Design definition for miniature imaging spectrograph***

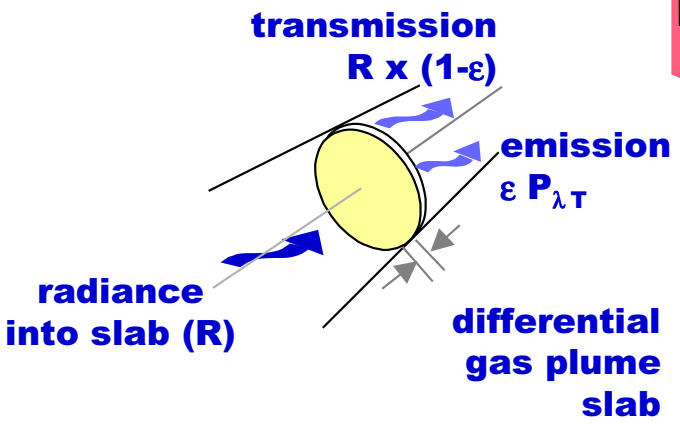
VOC plume monitor req't definition

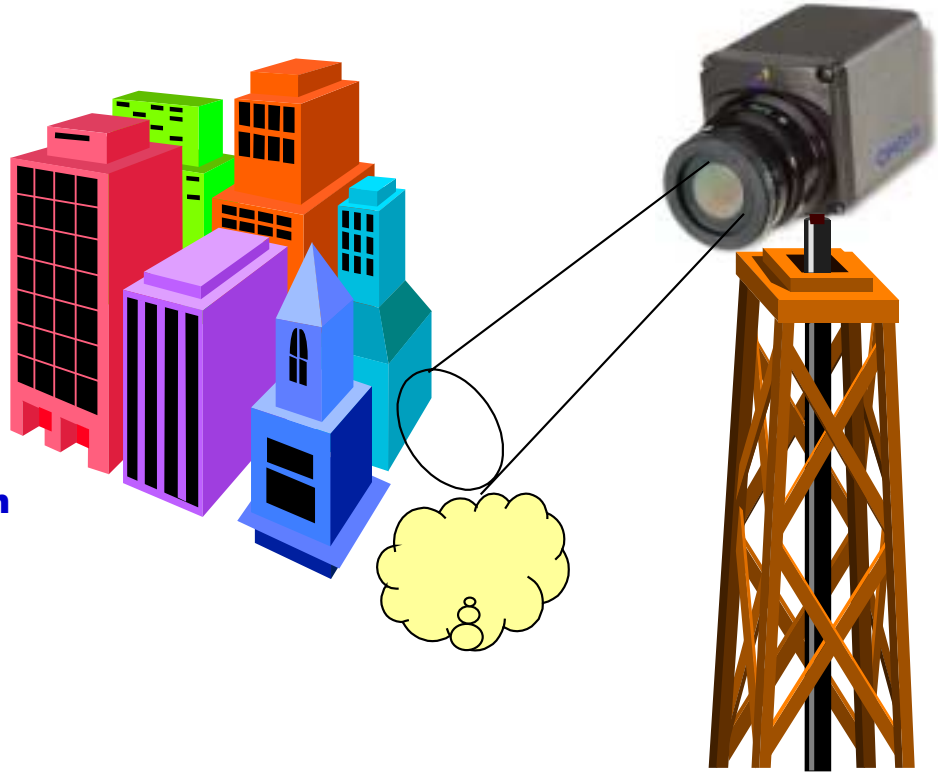
- **Point sensors are awkward: can miss unexpected leak sites**
- **Remote (stand-off) spectra: gas presence, not precise location**
- **Multi-spectral imaging: alignment/throughput in compact field unit**

VOC plume monitor req't definition

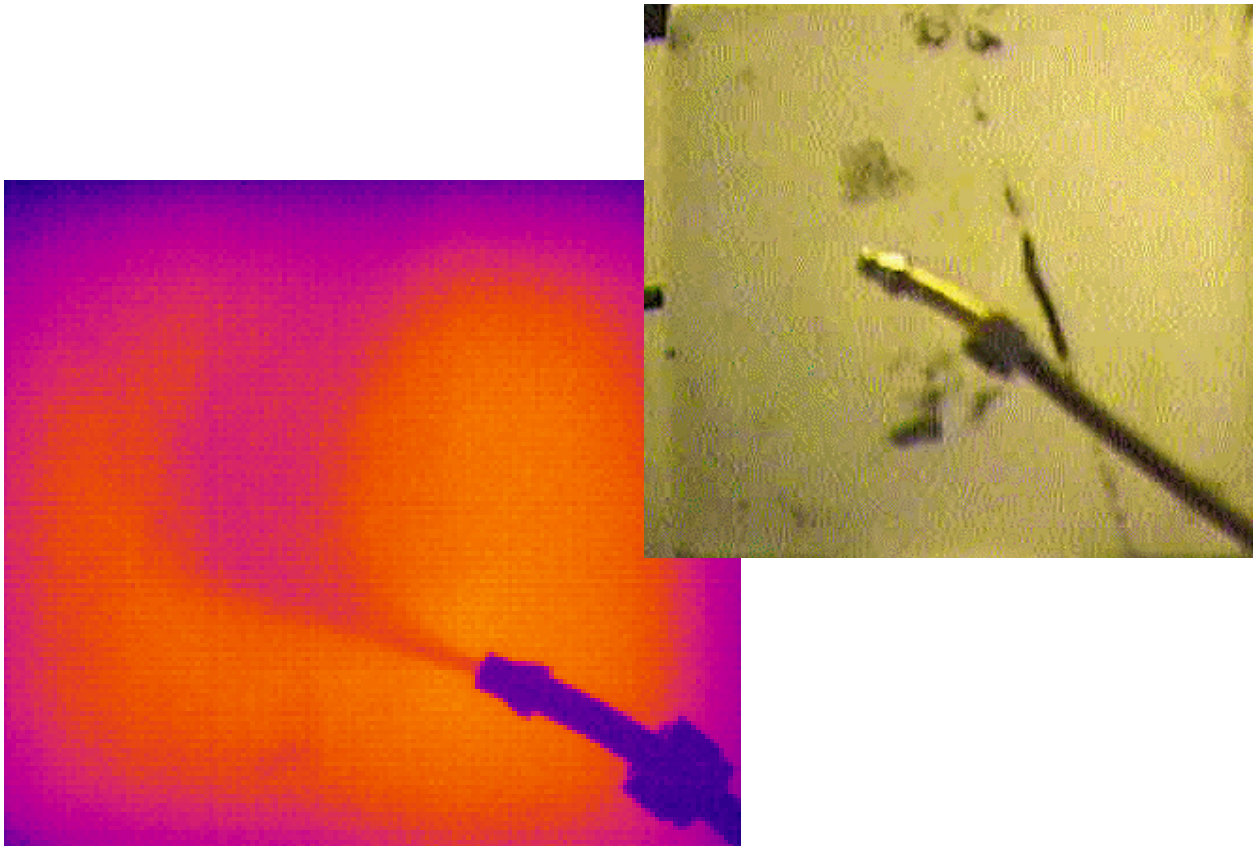
- **Spectral filter bandwidth: trade-off sensitivity and specificity**
- **Higher throughput achievable through shared optics**
- **Signal processing helps**

- **Alignment**
- **Throughput**
- **Stability**



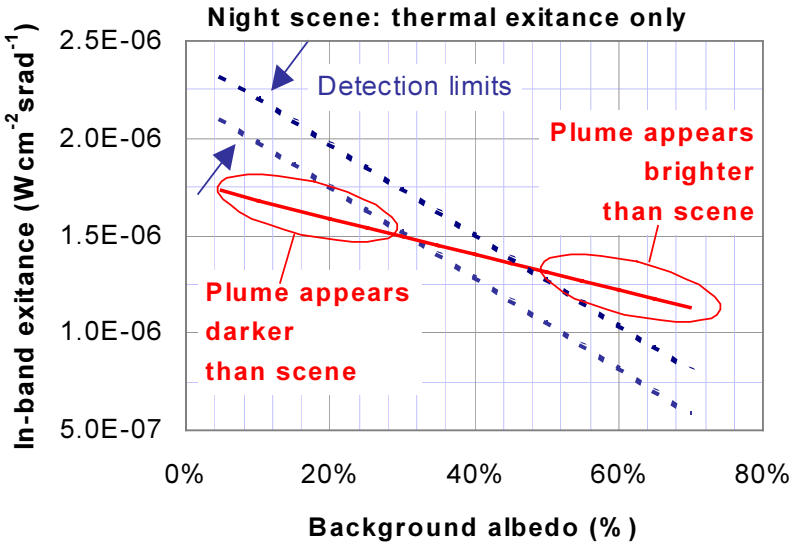


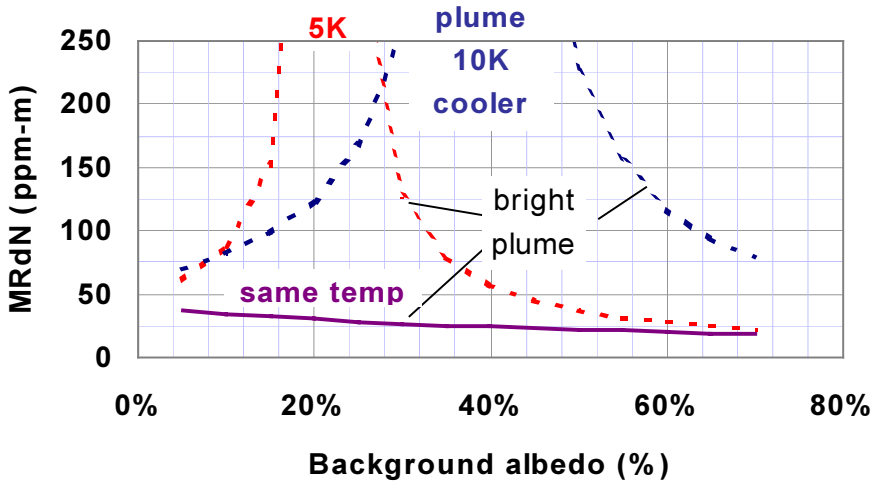
Mid-IR plume contrast: temp and spectrum



Band-pass filtered infrared image shows gas plume against flat, warm background

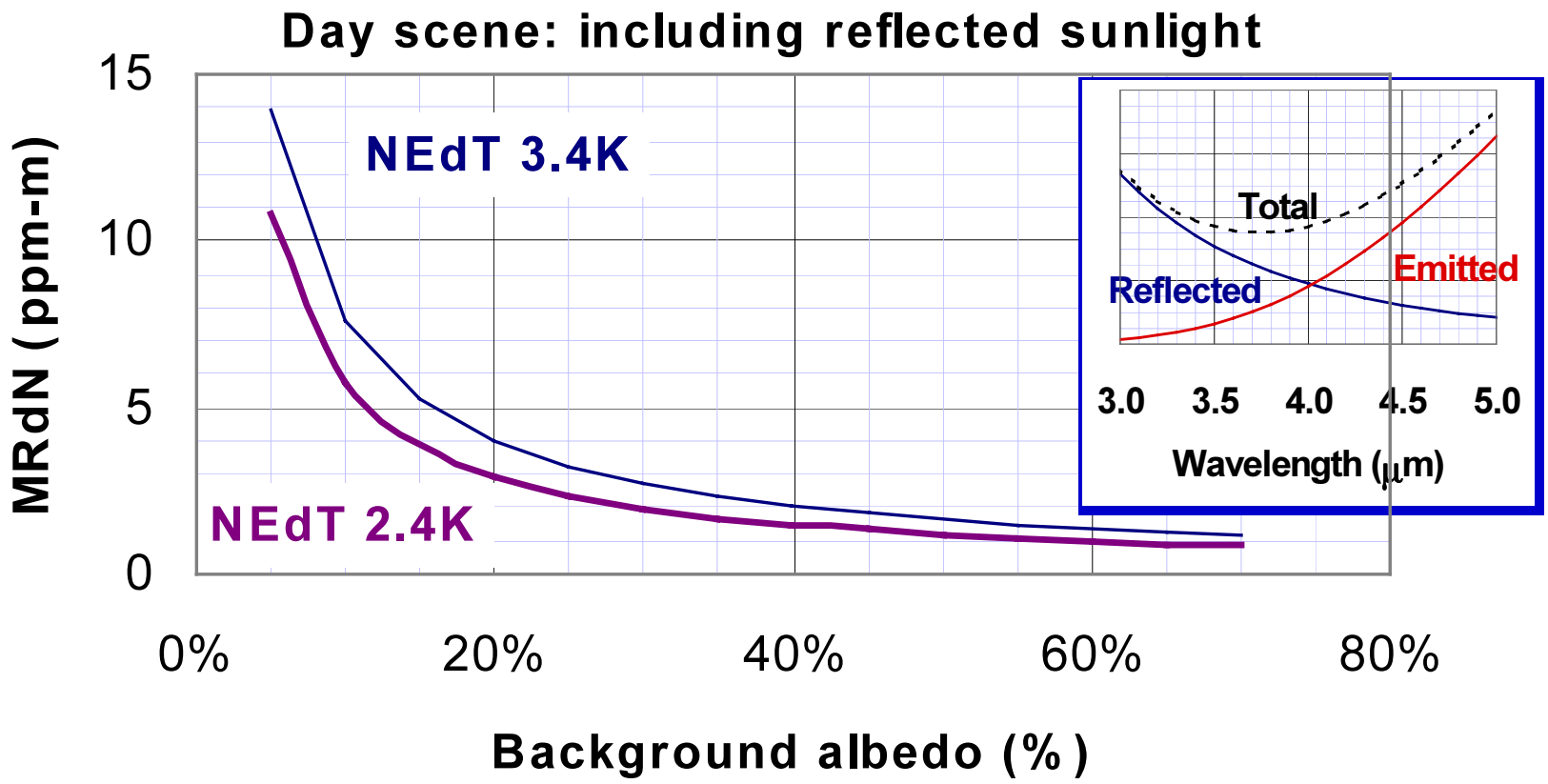
Mid-IR plume contrast: temp and spectrum





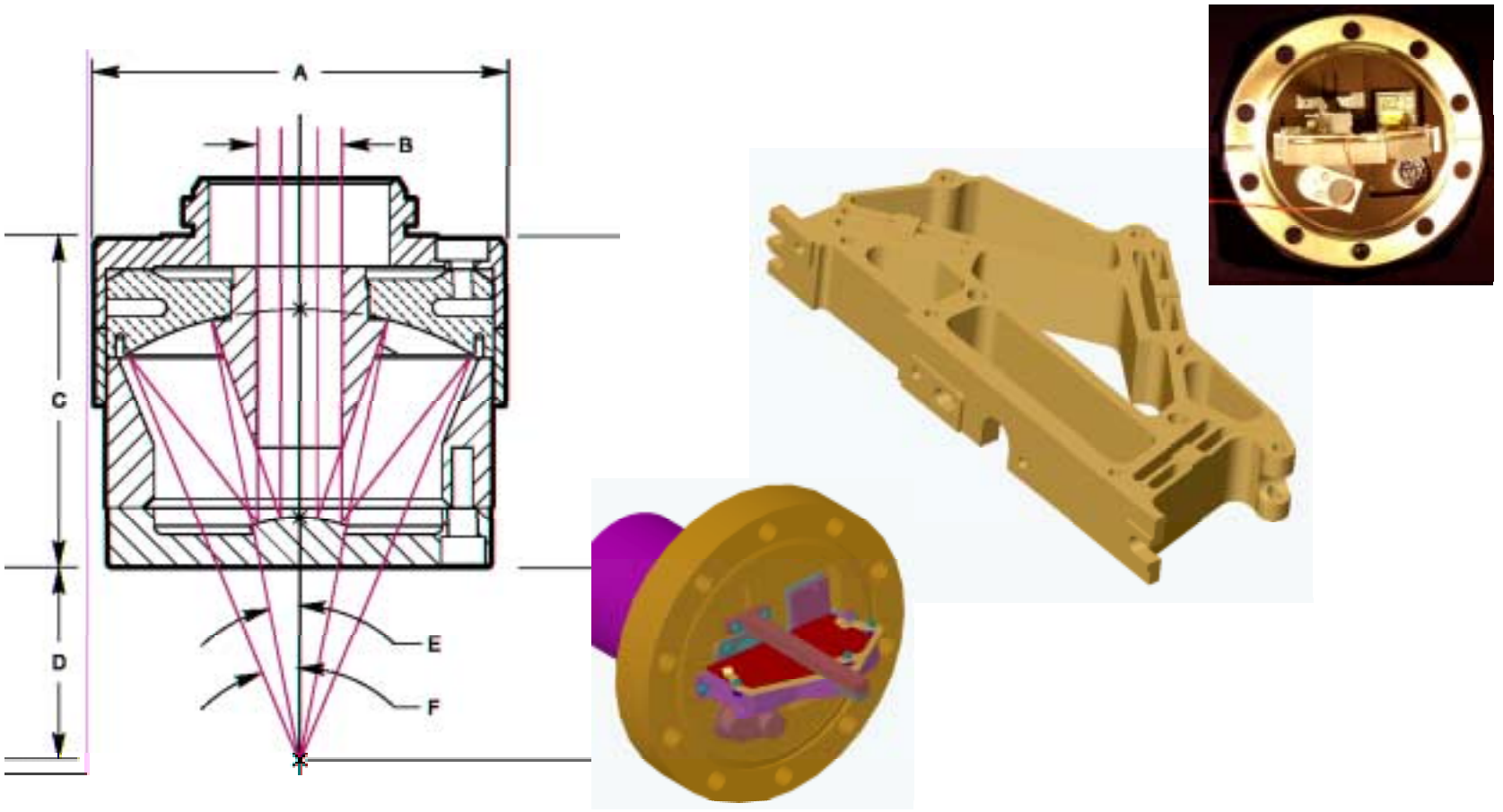
Thermal emission: gas plume can be brighter or darker than background (or invisible) depending on background spectral content and temperature

Mid-IR plume contrast: temp and spectrum



At 3.3 um wavelength, reflected sunlight dominates: reduces background clutter

Brassboard unit: achievable alignment + throughput



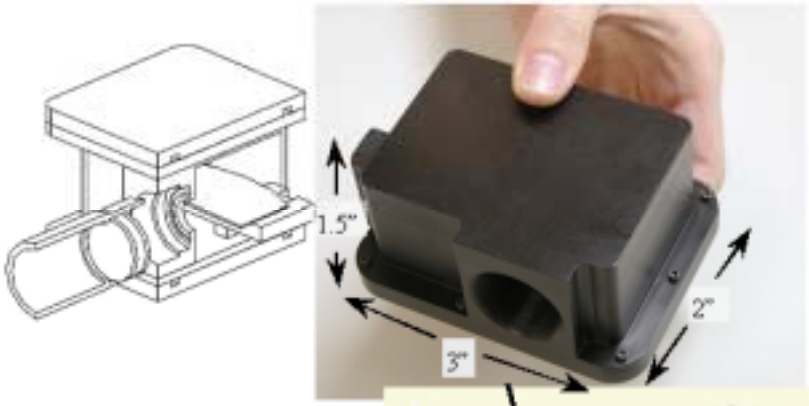
Waveguide micro-spectrograph integrated with IR microscope objective

Field test: alignment/package and throughput model

Brassboard unit measures CO_2 SO_2 evolution from active lava eruption

Technical Progress and Outlook

Future Technical Milestones/Goals



*Integration of the **MicroSpec** with the i*
camera. The analyzer will mounted ab
the camera lens and aligned to target t
center of the camera's field-of-view.

Technical Progress and Outlook

- **Expected progress toward milestones/goals**
  - ***Phase II project proposal submitted***
  - ***FY03 -- complete detailed design, signal processing***
  - ***FY04 -- sub-assembly tests and validation***
  - ***FY05 -- integrate and test imaging spectrograph***

- **Possible barriers**
  - ***Thoughput with shared focal plane***
  - ***Boresight alignment tolerance over operating temp range***
  - ***Temp and mechanical stability under field conditions***

Summary

- **Initial study project showed IOF interest in spectral imaging**
- **Current regulatory compliance monitoring is awkward**
- **Leaks/spills from < 1% of sites monitored responsible for bulk of environmental, process and energy cost**
- **Need spectral imaging to readily identify and locate leak sites**

- **Trace VOC detection modeled over cluttered backgrounds**
- **Model validated with brassboard spectrometer test data**
- **Alignment and througput are critical**

- **Next phase will develop imaging spectrograph VOC leak monitor**